Wayne Boblitt
Chuck Singer

6th Annual Systems Engineering Conference

Risk Management of Aircraft Wiring System Oct. 23, 2003

Presentation Outline

- NAVAIR Wiring Systems Branch
- Wiring Problem/Fleet Metrics
- Arc Tracking & Kapton Wiring
- Hazardous Risk Matrix and Analysis
- Risk Mitigation Approaches
  - Training
  - Selective Rewire
  - Total Rewire
  - Arc Fault Circuit Breakers
  - Apply advanced diagnostic techniques
- Wiring Risk Mitigation Options & Analysis
- Conclusions

NAVAIR Wiring Systems Branch

We Are Responsible For Three Things

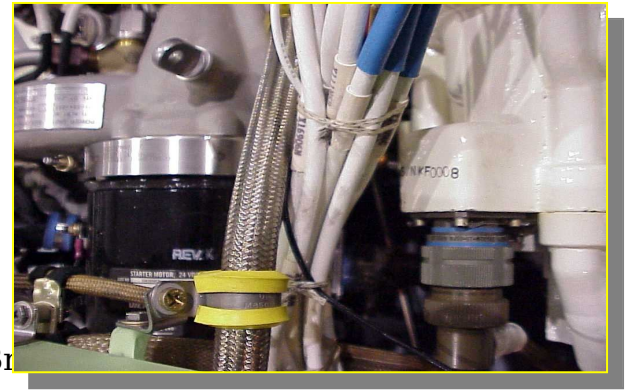
1. We Ensure That the Fleet and the OEMs Get Good Pa

- Maintain Qualified Products Lists (Suppliers) Backed up by Testing.
- Maintain and Transition Specifications

2. We Ensure Adequate Wiring System Designs and Ir

- Assess New Aircraft Wiring Installations As Well As Third Party Modifications
- Evaluate Installations for SOF, Workmanship, Performance and Maintenance Issues
- Review and Approve Flight Clearance Requests

3. We Ensure Aircraft Wiring System Integrity Throughout Its Life Cycle



- Monitor and Analyze Data
  - Quantify Risk and Recommend Solutions and Options
- Aging Wiring System Assessments
- Ensure That Fleet Gets Proper Training
- Ensure That Wiring Maintenance Manuals Are up to Date
- Ensure That Proper Tooling is Available
- Ensure That Technology Solutions Meet Fleet Needs (Arc Fault Circuit Br

Points of Contact

- Wayne Boblitt - Wiring Systems Branch Head
  - (301) 342-0808
- David Harrell - Engineering/IPT Lead
  - (301) 342-0813
- Jerome Collins - Science and Technology Lead
  - (301) 757-0868
- Pat Merrill - Wiring Systems Assessment Team Lead
  - (301) 342-0822
- Mike Peppas - QPL Lead
  - (301) 342-0857

NAVAIR has 45 people who work wiring.

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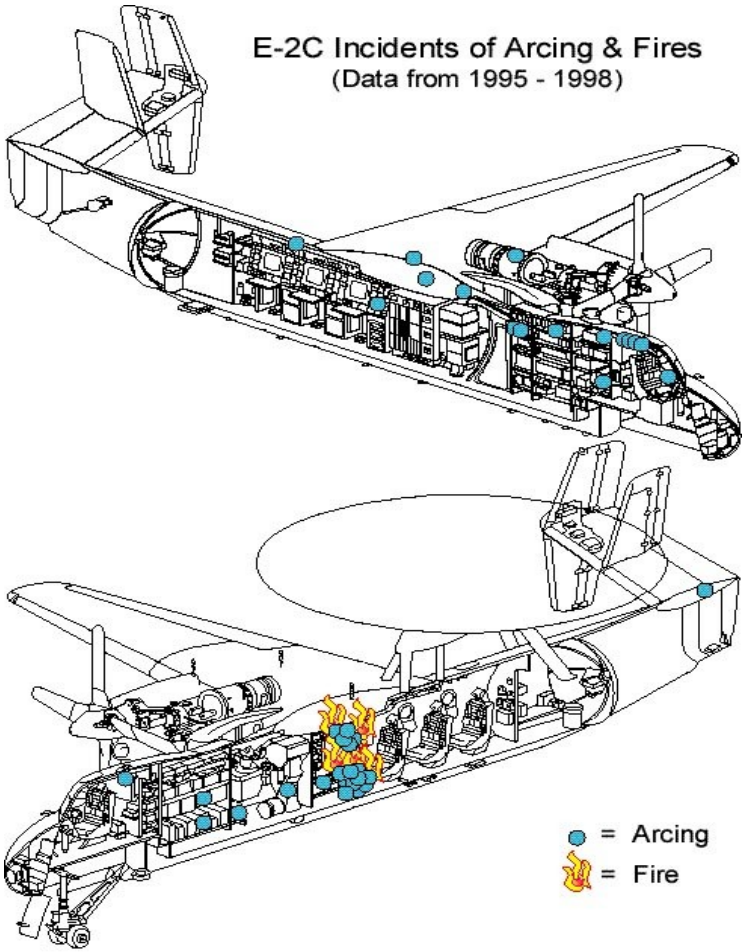
Wiring Problem

***** 30 months of fleet data ******

- 2.5 electrical fires/month - Lost 2 aircraft due to electrical fires
- Averaging 1400 mission aborts/year (540 in-flight aborts/year)
- 1-2M operational man-hours/year spent troubleshooting/repairing wire problems

- Spending $94M/Year due to false equipment removals across the fleet caused by external wiring problems

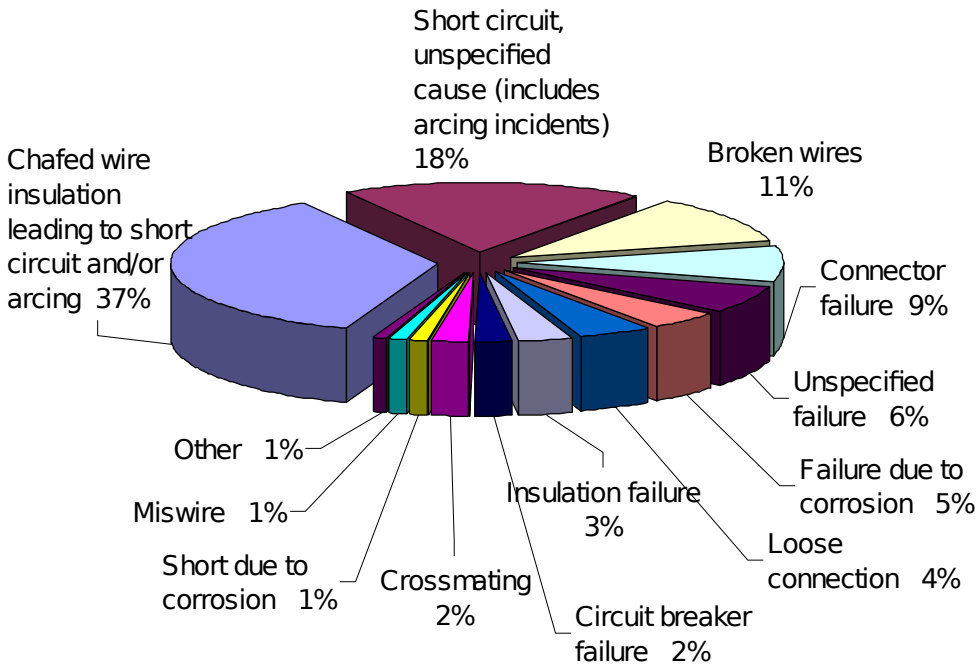


Aircraft Wiring is the number 2 safety concern of the fleet. Source: 2002 Avionics OAG

Metrics and Wire Failure Modes

Quarterly Metrics

- Inventory
- Flight Hours
- Readiness (NMC)
- Availability (Aborts)
- Safety (Mishaps)
- Reliability (MTBF)
- Maintainability (MMH)
- Supportability (MFHBCC)
- O&S Costs (M&S Costs)


Short circuit, unspecified cause (includes arcing incidents) 18%
Broken wires 11%
Chafed wire insulation leading to short circuit and/or arcing 37%
Connector failure 9%
Unspecified failure 6%
Other 1%
Failure due to corrosion 5%
Miswire 1%
Insulation failure 3%
Loose connection 4%
Short due to corrosion 1%
Crossmating 2%
Circuit breaker failure 2%

Safety Data

Effectively 125 Non Mission Capable Aircraft/Year Due t

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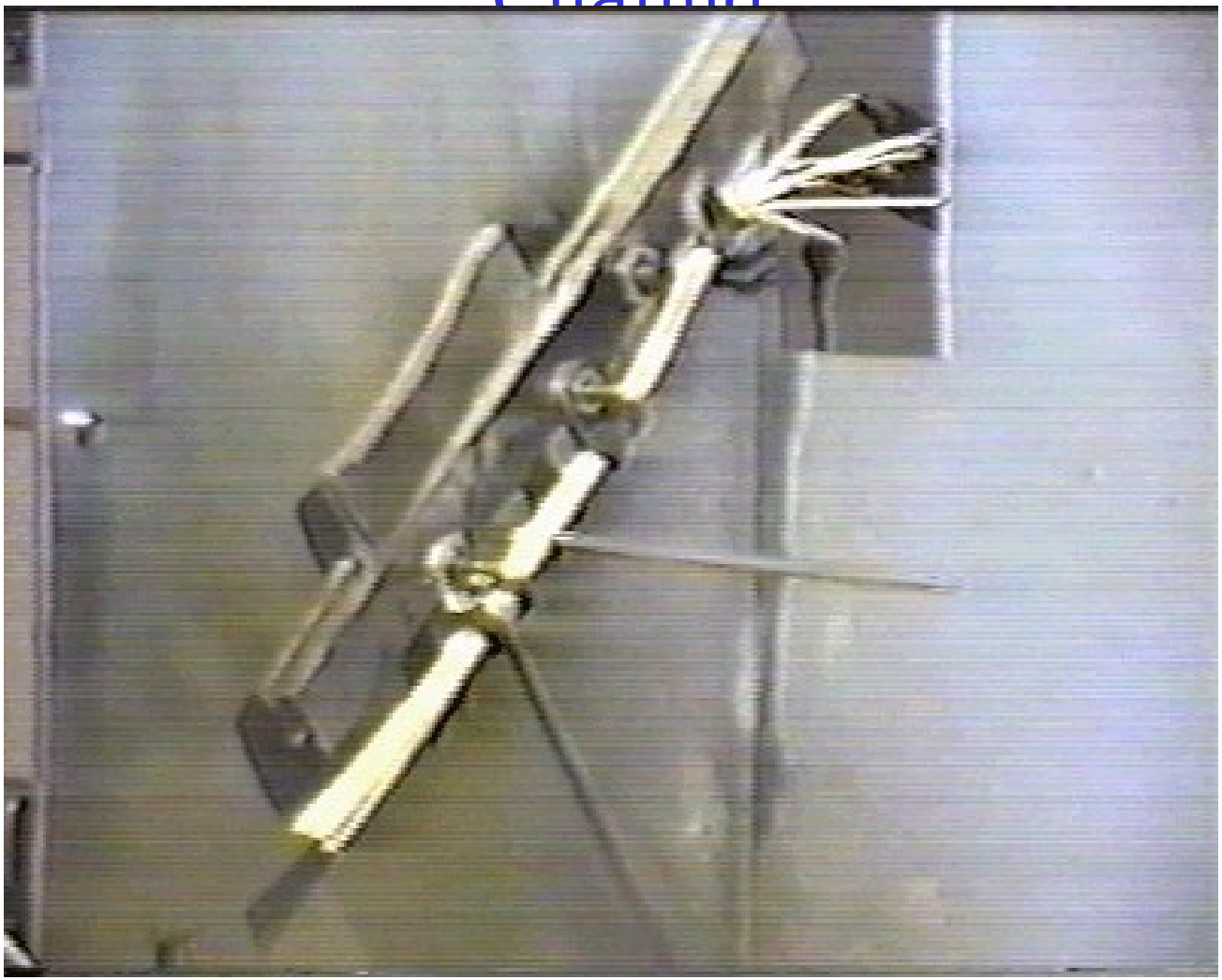
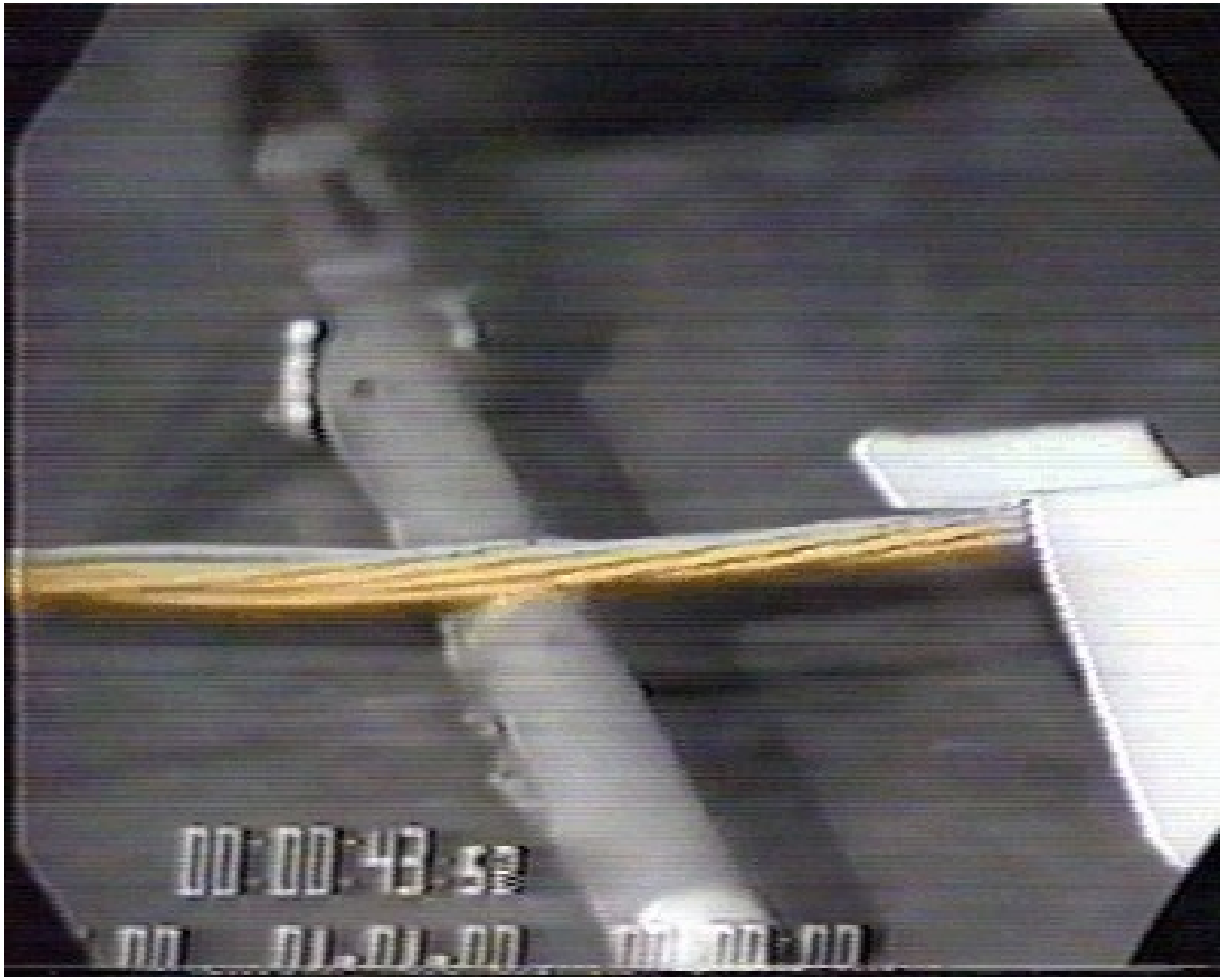
Aromatic Polyimide Insulated Wire Arc Tracking

Aromatic Polyimide Insulated Wire Chafing



Flaking Aromatic Polyimide Insulated Wire

Aromatic Polyimide Insulated Wire /Moisture Induced Arc



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Hazardous Risk Matrix

HAZARD CATEGORIZATION		SEVERITY			
		CATASTROPHIC (1)	CRITICAL (2)	MARGINAL (3)	NEGLIGIBLE (4)
FREQUENCY	FREQUENT (A) = or > 100/100K flt hrs	1	3	7	13
	PROBABLE (B) 10-99/100K flt hrs	2	5	9	16
	OCCASIONAL (C) 1.0-9.9/100K flt hrs	4	6	11	18
	REMOTE (D) 0.1-0.99/100K flt hrs	8	10	14	19
	IMPROBABLE (E) = or < 0.1/100K flt hrs	12	15	17	20

UNACCEPTABLE	ASN (RD&A) / Fleet Acceptance	ACCEPTABLE WITH REVIEW	PMA Acceptance
	1-5 HIGH SAFETY RISK		11-17 LOW SAFETY RIS
UNDESIRABLE	PEO / AIR-1.0 Acceptance	ACCEPTABLE WITHOUT REVIEW	IPT / FST / SSWG Acce
	6-10 MEDIUM SAFETY RISK		18-20 VERY LOW SAFE

Severity is the worst credible consequence of a hazard in terms of degree of injury, property damage or effect on mission defined

Catastrophic - Class A (damage > $1M / fatality / permanent total disability)

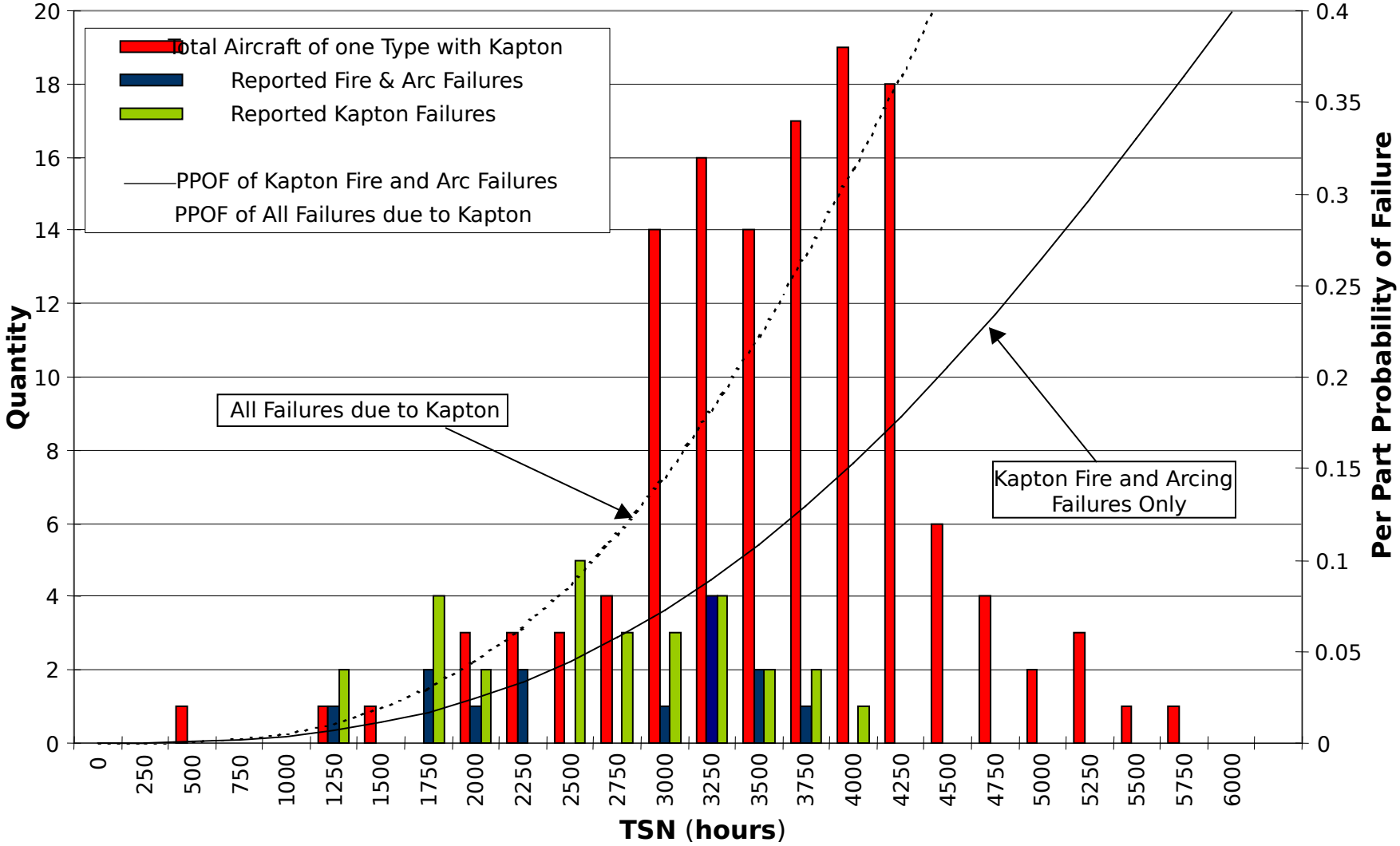
Critical - Class B ($200K < damage < $1M / permanent partial disability / hospitalization of 5 or more personnel)

Marginal - Class C ($10K < damage < $200K / injury results in 5 or more lost workdays)

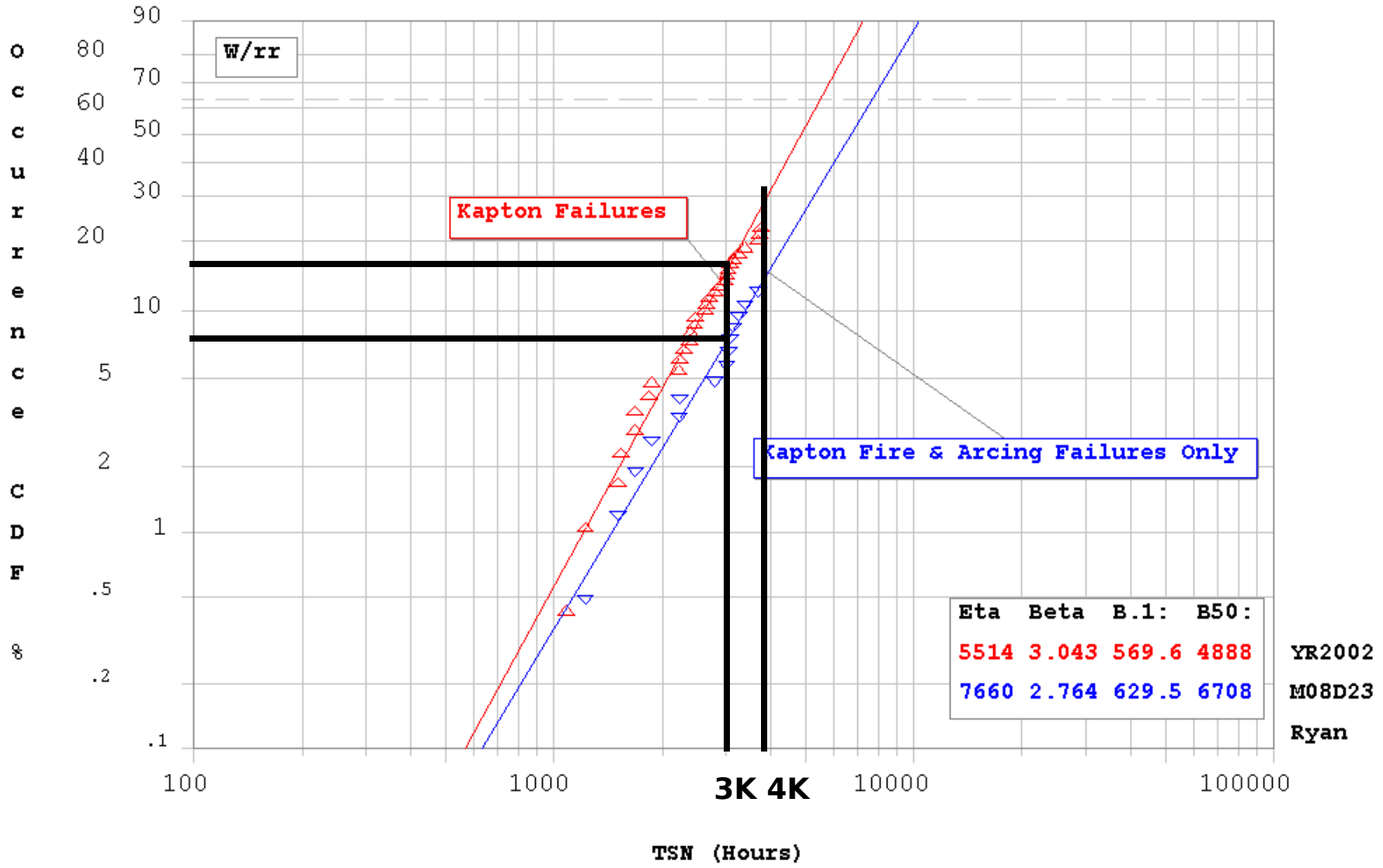
Negligible - All other injury/damage less than Class C

Probability of occurrence for discreet events may replace **Frequency** based upon the chart below:

Age Distribution of One Aircraft Type with Kapton Wiring
"Incomplete Data"



PPPOF of Kapton Wiring



Risk Mitigation Approaches

- **Increase Training - Focus on Wiring Care and Maintenance**
- **Perform Selective Rewire**
  - **Fleet has responded with a prioritized list of harnesses. ($9M to fabricate).**
  - **NADEP is gathering the information to support a rewire effort.**
- **Perform Total Rewire ($1M/Aircraft)**
- **Use Arc-Fault Circuit Breakers**
- **Apply Wiring Diagnostics Technology When**

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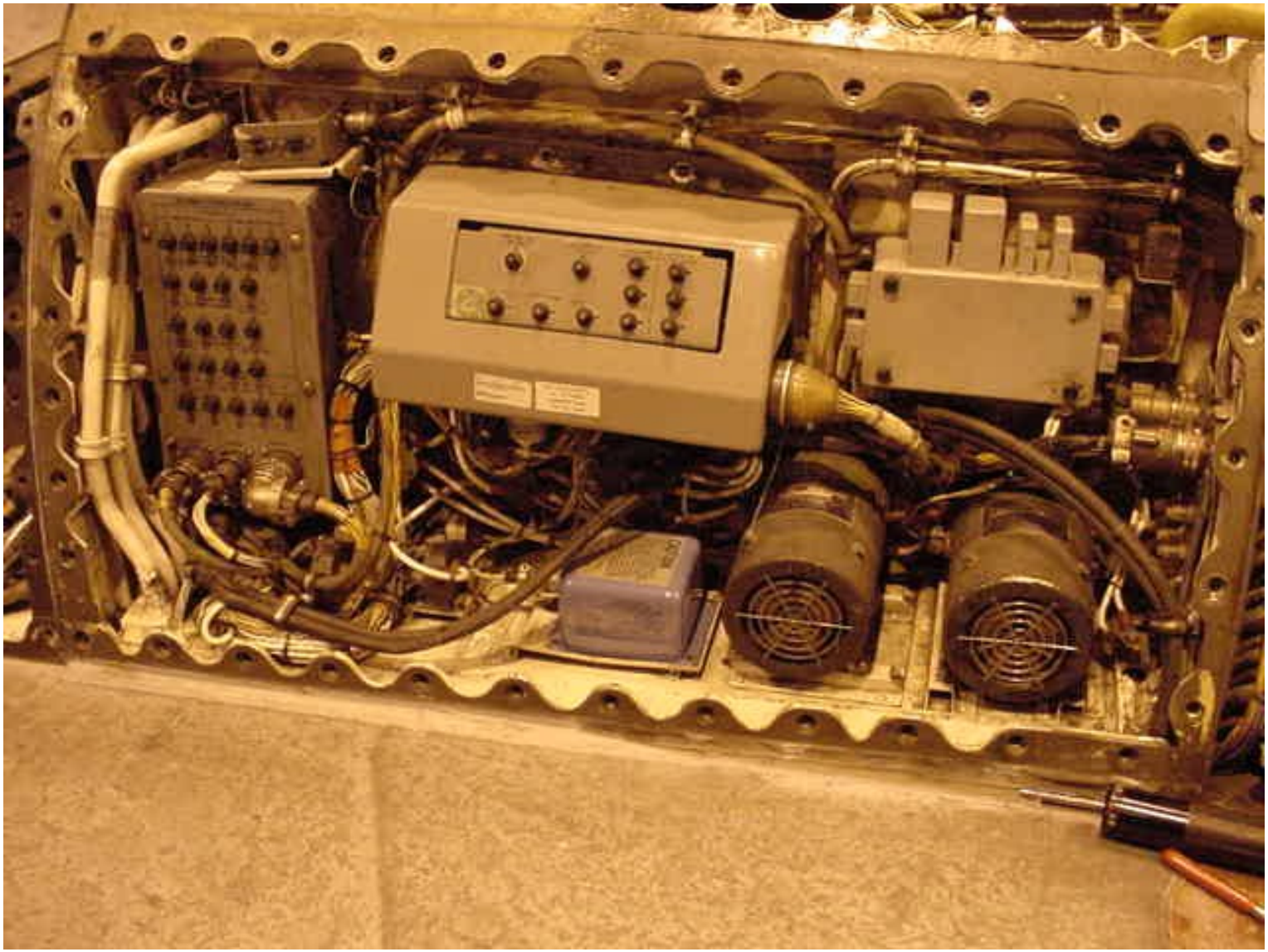
Wiring Inspection Training

NAVAIR has developed wiring inspection course.

Class Approach:

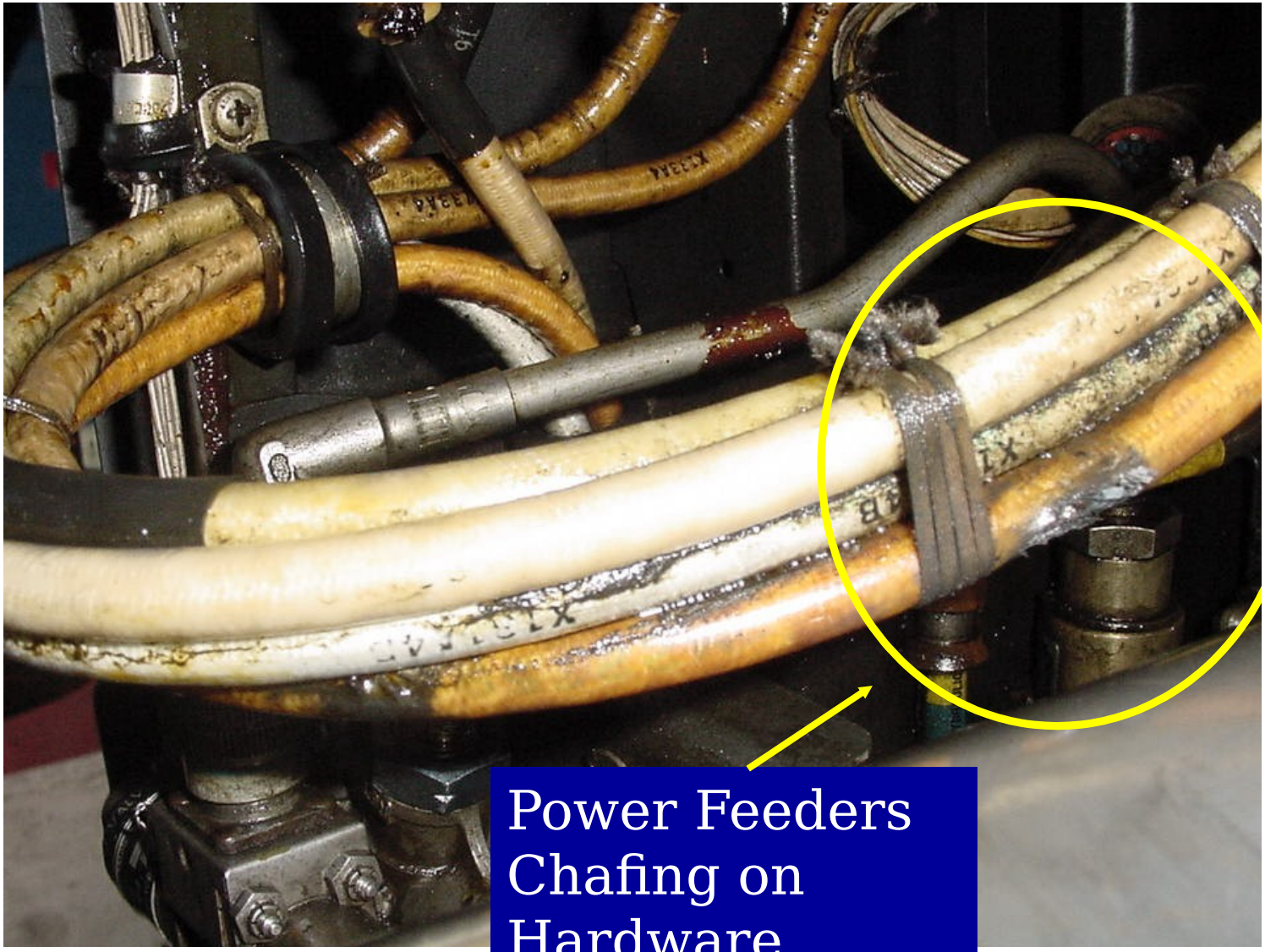
- **Explain common problems AIR-4.4.4.3 observes Fleet wide. Clamping, cable ties, wire routing, chafing, hardware use, connector types/proper stowage, combat repairs.**
- **Provide <u>Customized presentation</u> of squawks found on squadron aircraft and presented how they were found. Note: Aircraft was assessed on-site prior to the class to gain photos. <u>Interactive presentation</u>, "Here is a condition we found. What do you think is wrong here?**
- **Explain reasons for specifications and how they pertain to their aircraft. "Who the !!@@??%&# designed this stuff, anyway?"**
- **Provide hands-on training. On-Acft training allowing participants to practice some inspection techniques.**
- **Encourage proactive approach, find problems during Acft down times, look around after maintenance is complete.**

Training

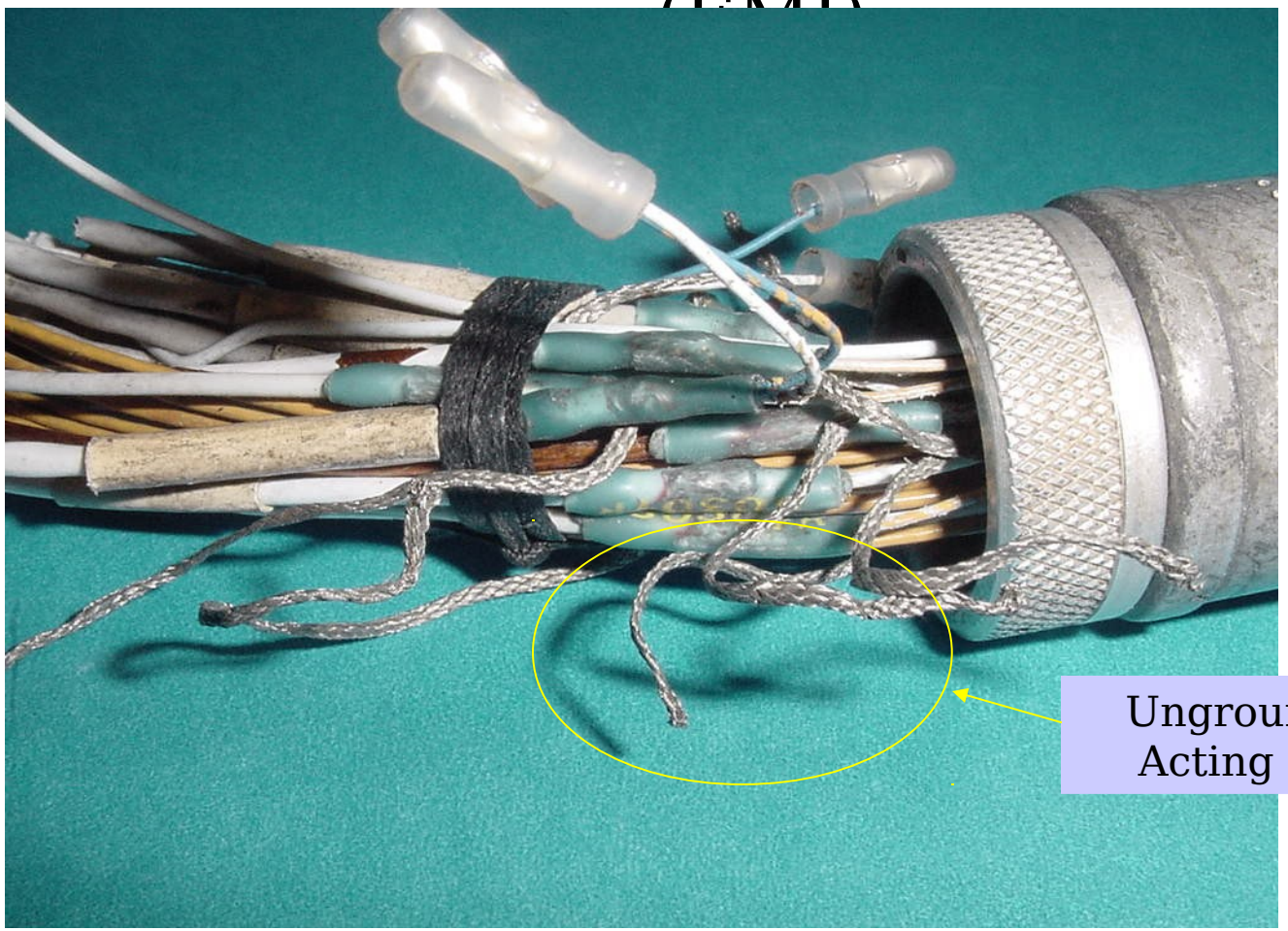


Training – Option 1

Training – Option 1

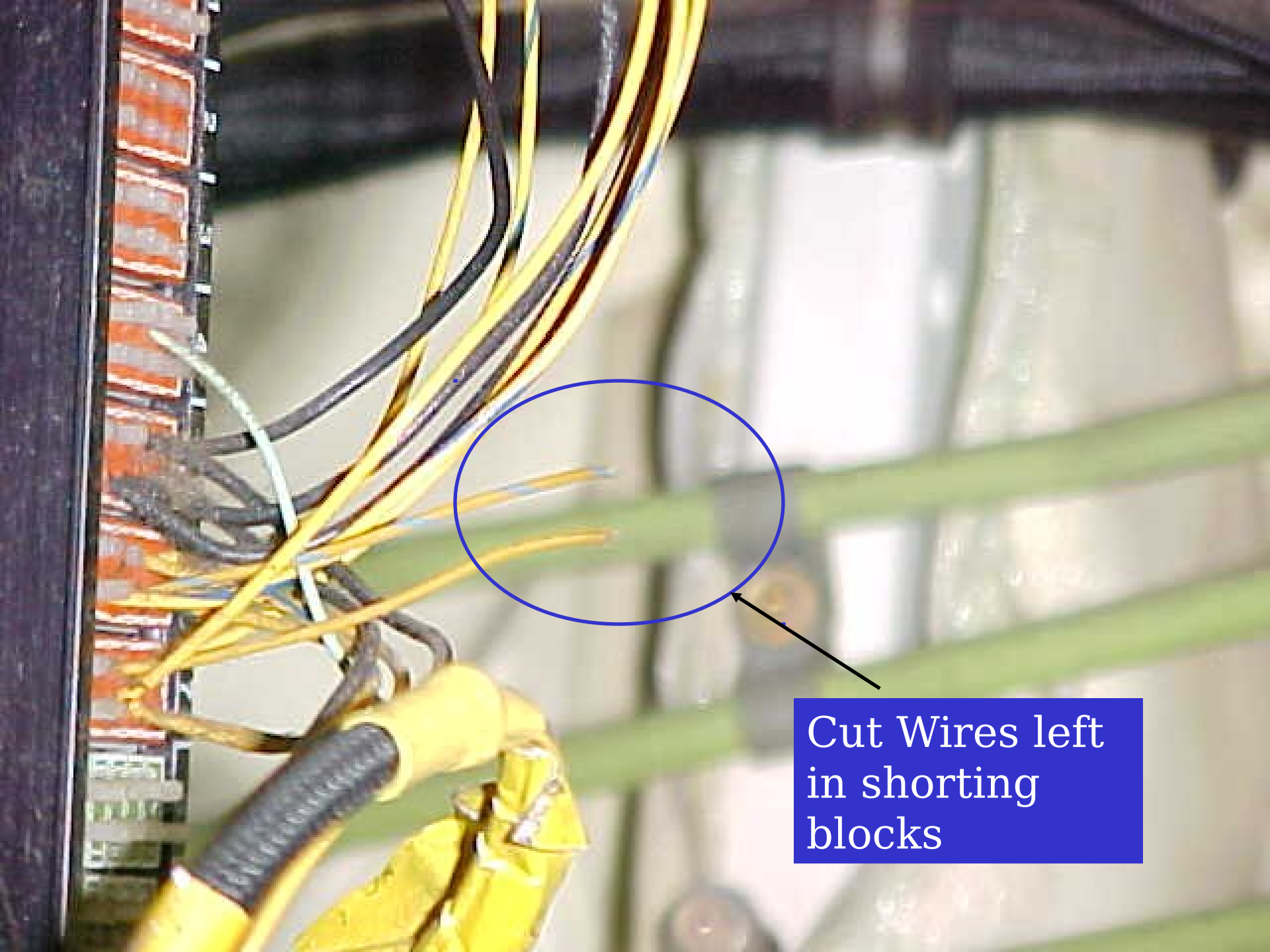


Electromagnetic Interference (EMI)



Grease covered over braided wire bundle lying on flight control cable.

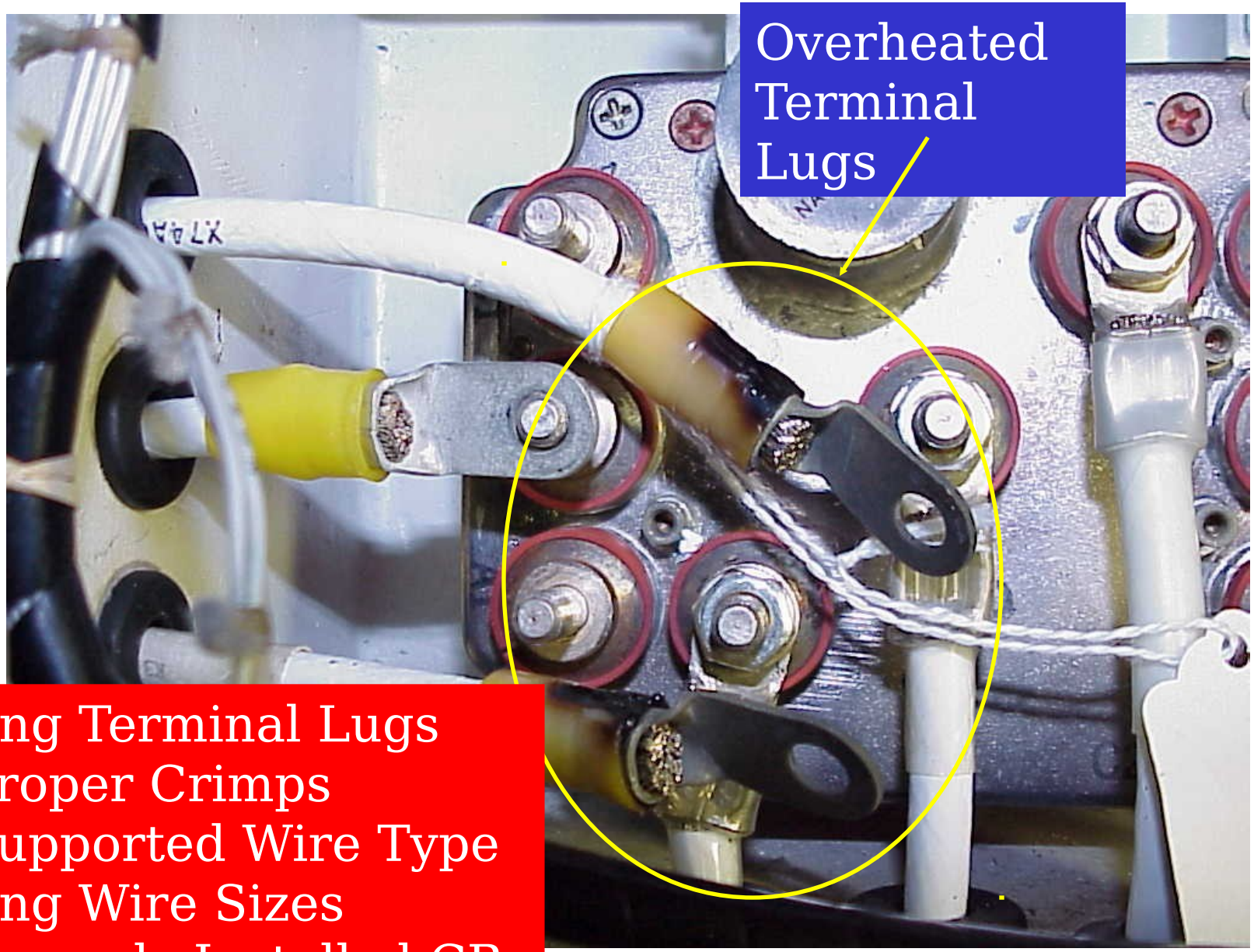
Clamped to hydraulic line for primary support and to take out slack.


Cut Wires left in shorting blocks

Wire Chafing on
Clamp Hardware

POWER FEEDERS AGAINST ADJACENT METAL BRAIDED FUEL LINE

Panel Screw Will Contact Flight Control

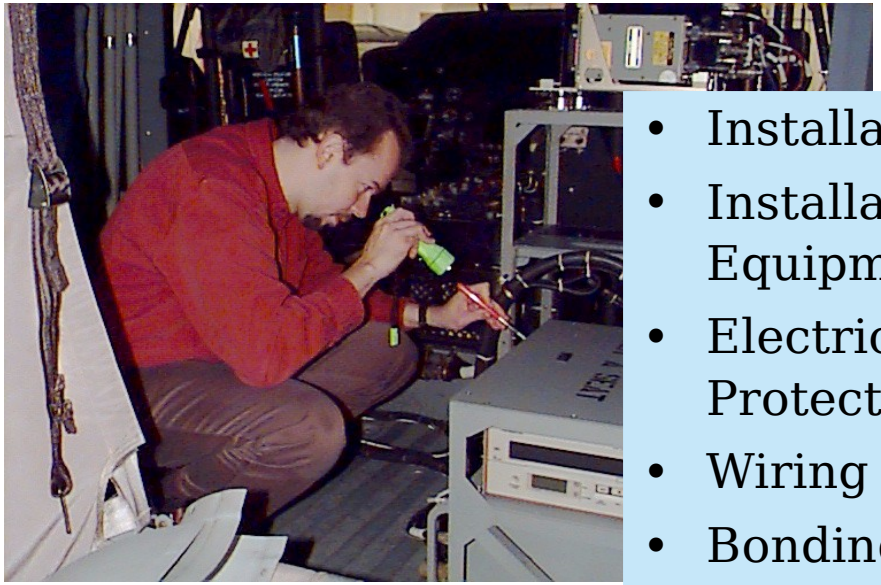


Wrong Terminal Lugs
Improper Crimps
Unsupported Wire Type
Wrong Wire Sizes
Improperly Installed CBs

Wiring System Assessments

- 30%-60%-90% In-Process Assessments
  - In-Process Development, Production and Modification Monitors
- Final/Acceptance Inspections
- Safety Inspections
- DT and INSURV Trials
- Aging Aircraft Condition Inspections

Assessment Focus



- Installation of Electrical/Electronic Wiring
- Installations of Electrical/Electronic Equipment
- Electrical Power Distribution Circuit Protection
- Wiring Terminations and Connectors
- Bonding, Grounding and Shielding
- Interference With Structures, Lines and Mechanical Systems
- Identification of Wiring and Equipment
- Consistency in Installations
- Workmanship Practices
- FOD Control

Class Comments

"Seeing the slides of our own aircraft really hit home"
"Should be mandatory training"

"This training gave a different way to inspect aircraft. Proper use of this training will only better this squadron"

"Slide presentation was very effective, especially slides used on squadron aircraft that was previously inspected (Not some old slides taken years ago)"
"I need to go back and train the rest of the division"

AF Sergeant: 90% of my wiring problems can be solved with

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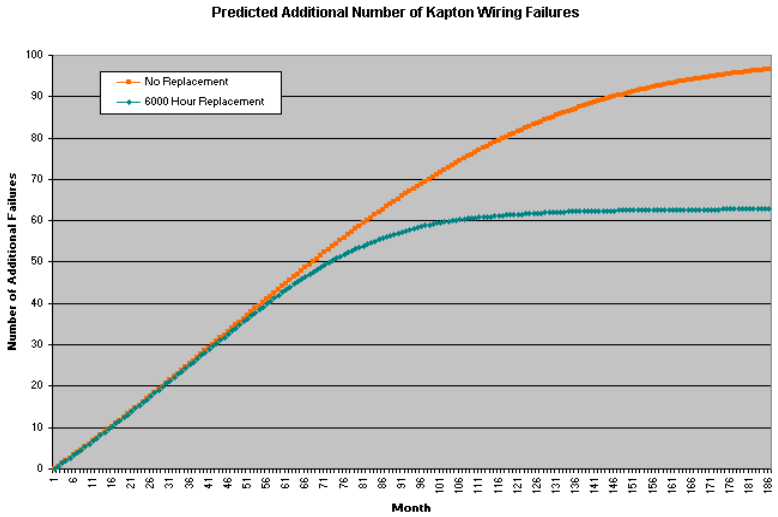
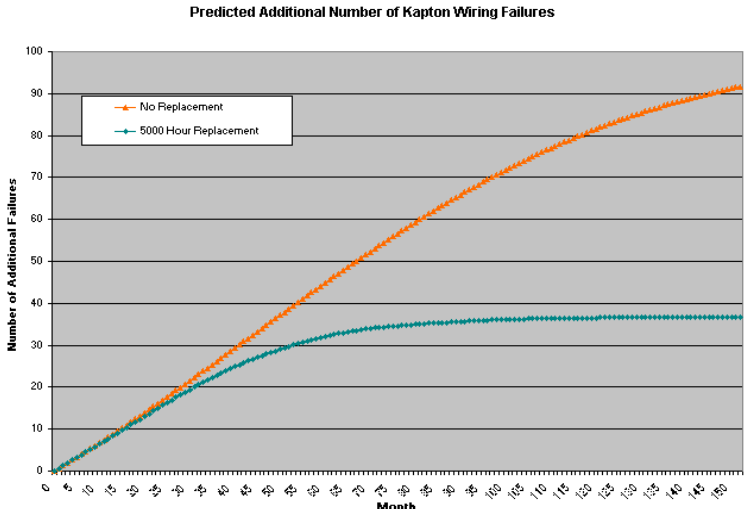
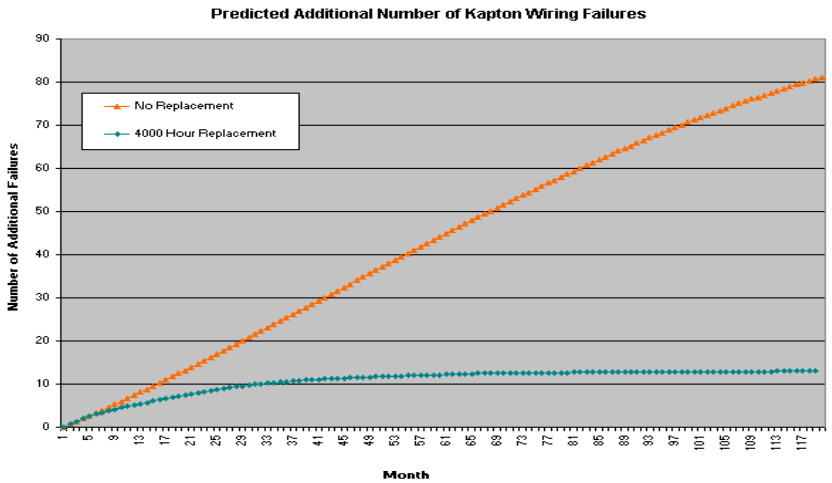
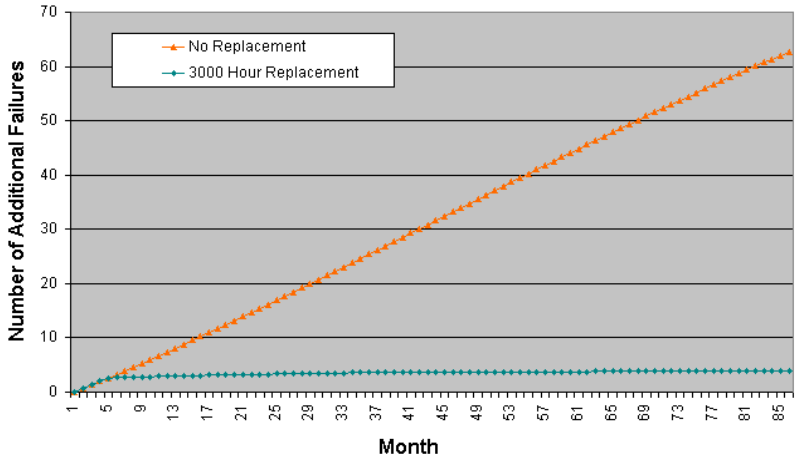
Total Aircraft Re-Wire

Reduces additional failures but does not eliminate them
Cost $1M per aircraft









Arc Fault Circuit Breake

Developmental Timeline

- Texas Instruments
- Eaton
- Ametek

- MS14105 & MS24571 Specs. will be voted on October, 2003
- QPL to follow in Oct.

Fiscal Year

00 01 02 03 04 05 06 07 08

Transport Aircraft

MS24571

Development | *Flight Test* | *Prod.* | *Install*

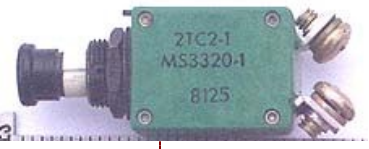
Current Status:

- Flying in C-9 and 727
- Available in FY05

ONR/FAA/AAIPT Component Impr Program

Fighter/Helo/Patrol A/C

MS3320



Begin Devel | *Lab Test* | *Ground Test* | *Flight Test* | **Prod.**

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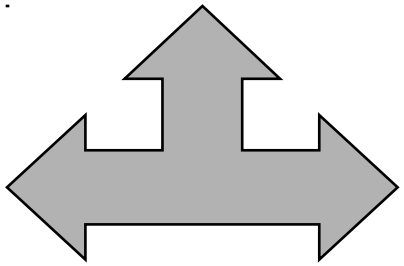
Ruggedized Laptop

Standing Wave Reflectometer - With Plain Text Display



Test Box/Expansion Units

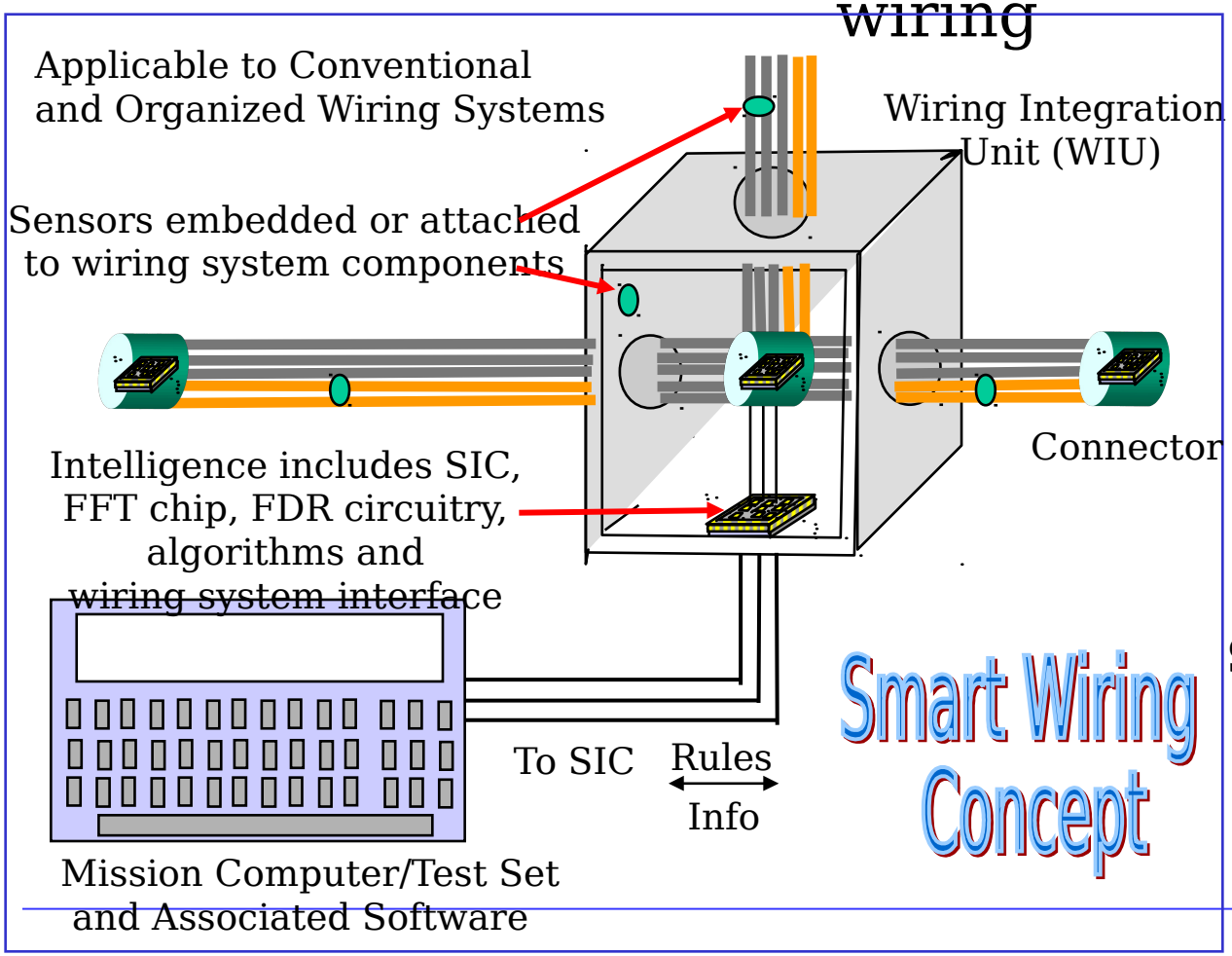
IMPLEMENTATION

- **O-LEVEL**
- **I-LEVEL**
- **DEPOT- *Starting Point***

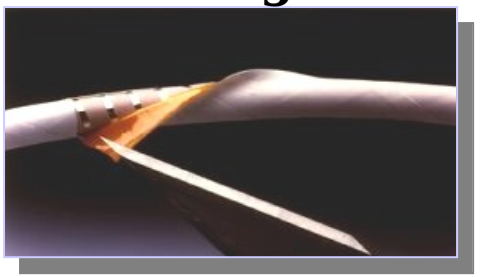
TEST SYSTEMS
(MIL-STD-810 EXPLOSIVE ENVIRONMENT)

SMART WIRING FOR AIRCRAFT
Description of Technology

Smart wiring is the embedding of intelligence and sensors in the wiring system to manage the health of the wiring

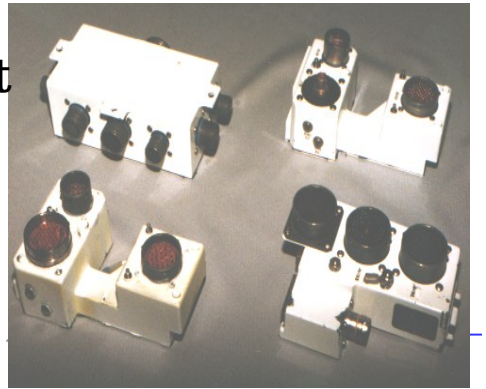

Applicable to Conventional and Organized Wiring Systems
Wiring Integration Unit (WIU)
Sensors embedded or attached to wiring system components
Connector
Intelligence includes SIC, FFT chip, FDR circuitry, algorithms and wiring system interface
To SIC
Rules
Info
Mission Computer/Test Set and Associated Software
Smart Wiring Concept

Smart Wiring Harness



Smart Connector

Smart WIU



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SIC

FLC Study

Single Wire
Breadboard

Wiring Diag. SBIR

Detection Technology
for Insulation Failures

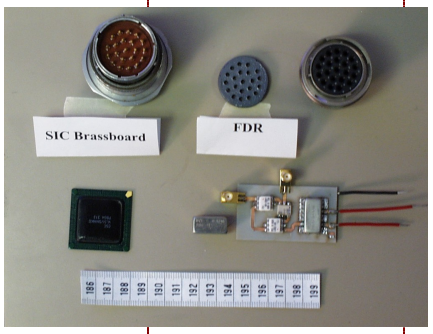
EMD/Transition
Lead: P-3, PMA-290A
Additional Retrofits: F/A-18, EA-6B, F-14,
AV-8B, V-22, JSF

Development

Flight Tes

ONR 6.2 Effort

ONR 6.3 Effort



USAF SBIR
Co-processor development

Smart Connectors

* ‘Hockey Puck’ connector saver
* Flight hardware processor/sensor development

SMART FIBER OPTIC OVERBRAID

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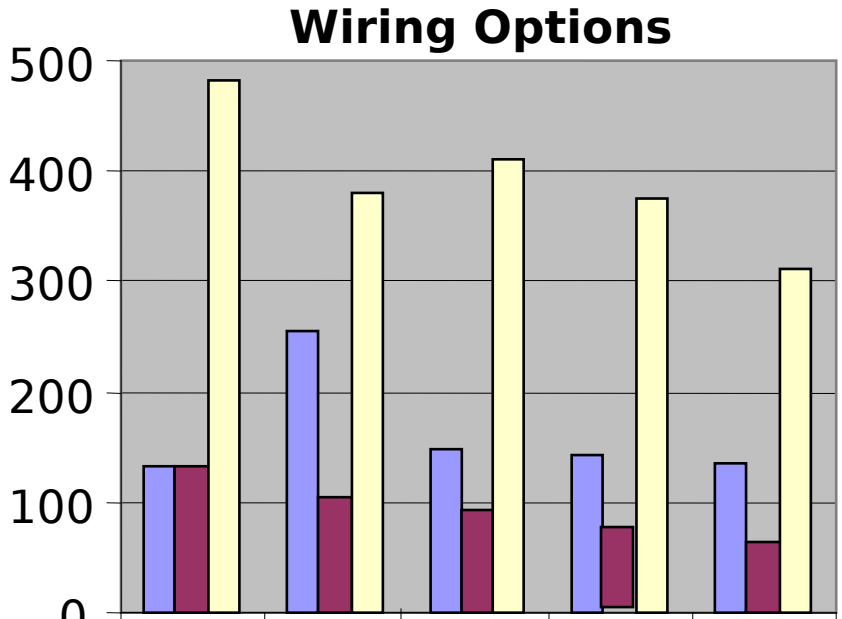
Wiring Risk Mitigation Options

Option	Action	Cost To Implement	Continued AC costs	NMC Aircraft
1	None	$0M	$8M/yr increasing to $16M/yr	8 increasing to 16
2	Total Re-wire	$150M	$8M/yr	8 increasing to 12 leveling off at 8
3	Selective Re-wire (SRW) + AFCB	$36.3M	$9M/yr	8 increasing to 10
4	SRW, AFCB, Off BWD	$41.3M	$3.5M/yr	8 decreasing to 7
5	**SWR, AFCB, Off BWD, On BWD**	**$48.3M**	**$2M**	**8 decreasing to 4**

Recommend Funding for Option 5

Cost/NMC AC Years/Aborts vs. Wiring Options Ove Ten Years



	1	2	3	4	5
Total Cost (M$)	132	254.3	148.8	143.1	135.5
Total NMC Aircraft Years	132	104	90	75	66
Total Aborts	483	379	410	374	312
HRI Rating After Implementation	**4,5**	**14**	**6**	**10**	**14**

1. None
2. Total Rewire
3. Selective Rewire (SWR) + AFCB
4. SWR+AFCB+ Off Board Diagnostics
5. SWR+AFCB+ Off/On Board Diagnostics

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Platform

Kapton Wiring Deterioration

- Hazard Description:

  Deterioration of Kapton™ wiring insulation causes wire to wire shorting and arcing resulting in fires, loss/degradation of AFCS, erroneous instrument readings, power surges, failure of aircraft subsystems

- HRI: 2C (6) Medium Risk

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	IMPROBABLE (E) =or < 0.1/100K flt hrs			

- **Current Mitigation**:
  - Fleet replacement of damaged wiring at O/I-Level
  - Replacement of damaged wiring at SDLM
- **Final Resolution**:
  - **Plan:**
    - Short Term: Training. Wiring team inspection of aircraft and development of inspection training program for fleet.
    - Mid Term: Targeted prioritized wire harness replacement. Depot field teams & SDLM replacement of critical wiring harnesses. Depot currently reviewing TYCOM/Fleet wiring prioritization survey. Plan for replacement still to be worked out.
    - Long Term: Removal of Kapton™ wiring from all aircraft during SLEP. AFCB, Off board and On-Board Diagnostics Funding Needs to be POMed.
  - **Residual Risk:**
    - Short Term: Potentially reduce frequency of occurrence (remains medium risk).
    - Mid Term: Reduction in frequency of occurrence (likely to remain medium risk).
    - Long Term: Elimination of hazard.

Any Questions?